New Cosmological Data and the Values of the Fundamental Parameters
IAU Symposium, Vol. 201, 2005
Anthony Lasenby and Althea Wilkinson, eds.

Period–Luminosity–Shape of Light Curve Relation for Cepheids in LMC and SMC

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Abstract. In this paper we report our analysis of the period–luminosity–shape of light curve (P–L–S) relation. The data we used came from LMC and SMC Cepheid light curves produced by OGLE-II microlensing survey. We used Principal Components Analysis of covariance matrix of the sets for Cepheids in LMC and SMC separately. Our calibrating set was bounded to long period classical Cepheids pulsating in fundamental mode. The results are used to derive a method for estimation of distances from light curve shape.

1. Calibration of Period–Luminosity–Shape relation

To improve the distances obtained from cepheids, the P-L relation is replaced with the P-L-C relation, sometimes with additional reddenning and metallicity corrections (Feast 1999, Tanvir 1999). We investigate whether an improved relation may be obtained employing the shape of the light curve. For this purpose we callibrate the period-luminosity-shape relation (P-L-S) using the rich sample of the LMC and SMC Cepheids produced by OGLE-II microlensing survey (Udalski et al. 1999a, Udalski et al. 1999b). To avoid problems with the 10 days resonance we use stars with period $\log P > 1.05$.

We used Fourier coefficients of I-band light curves and Wessenheit Index magnitude W_I. Because of distance and metallicity difference we analyzed LMC and SMC Cepheids separately. Our analysis of Cepheids light curves proceeds in three steps. First we calculate the covariance matrix of period, W_I and Fourier coefficients. Next, we identify a relation between them by the principal component analysis. By solving the relation for W_I we obtain the P-L-S relation suitable for distance determination:

$$W_I = 16.79 - 1.02 \log P - 2.96\, a_1 - 1.18\, R_{21} - 0.80\, \phi_{21} \quad (1)$$
$$W_I = 19.65 - 1.65 \log P - 1.33\, a_1 - 2.99\, R_{21} - 1.25\, \phi_{21} \quad (2)$$

These are the relations for the Wesenheit index of stars at distances equal to the LMC and SMC respectively.

https://doi.org/10.1017/S0074180900216768 Published online by Cambridge University Press

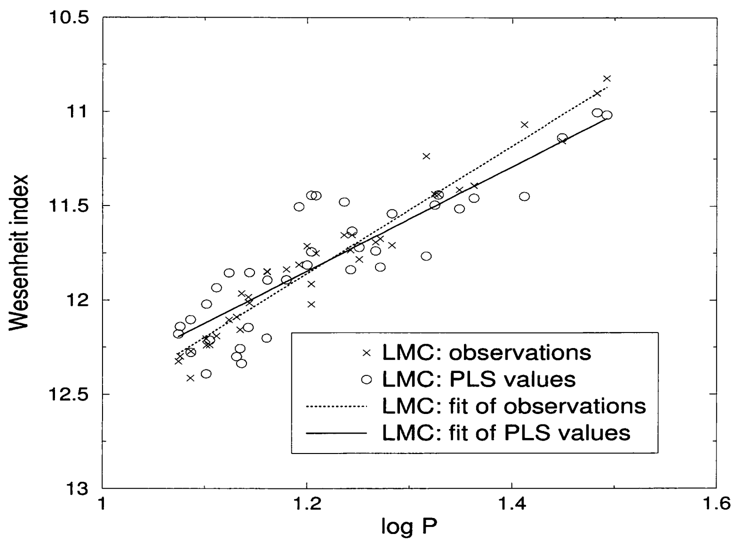

Figure 1. P-L relations for observed and derived W_I

2. Verification of the derived luminosity

In order to test our new distance estimation methods we apply it to our calibration set of Cepheids from the Magellanic Clouds. Then we compare the scatter of the observed and derived from shape W_I around a linear P-L relation. Both P-L relations for LMC are shown on Figure 1. The scatter around P-L relation for LMC with observed W_I is $\sigma = 0.09$ while for derived W_I $\sigma = 0.11$. The same relations for SMC gives scatter respectively 0.13 and 0.15.

Except for small systematic errors due to nonlinear difference in medium luminosity in I and V, our P-L-S relation is extinction independent. Our P-L-S relation produces scatter of derived luminocities only 20 percent larger than the intrinsic scatter of Cepheids in the clouds. For $n = 10$ Cepheids detected in a galaxy this effect causes random error of its distance modulus of order $0.11/\sqrt{10} = 0.03$ mag (or 0.05 mag), a small value by cosmological standards.

Acknowledgments. Present work was supported by KBN grant No. 2 P03D 018 18 and 2 P03D 015 18.

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